HUMS Into the Maintenance Process

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Abstract

Life Cycle Cost (LCC) is one of the most important issues in the helicopter total costs of ownership. The HUM systems look as the most promising tools to reduce the LCC, provided they can be exploited at their maximum extent.
This paper is an overview on the Agusta way to implement and make use of the HUM systems, with particular emphasis on the helicopter usage monitoring, the transmission vibration monitoring and the data management as they are implemented on the Italian Navy version of the EH101 (EH101 MMI).

Introduction

Agusta has been designing diagnostic systems since 1985, when a HUM system had to be developed for the EH101 programme. At that time HUMS basically meant vibration monitoring for the gearboxes; usage monitoring, instead, was still something to be devised out. Even at that early time it was clear that usage monitoring, even though implemented in a simple way, but exploited at the correct level, could turn the maintenance procedures upside down. In other words, the introduction of a computerised method for the detection of component usage, along with a ground station for the data management, could not escape from being seen as a new maintenance management wedge into well consolidated ILS architectures, at least for customers as large as the armed forces.
In the following chapters some details of the HUM system are given together with the application in the Italian Navy and the implications for the extension to the civil market.

List of Acronyms

BIT	Built In Test
CCU	Central Control Unit
COTS	Commercial Off The Shelf
DTD	Data Transfer Device
DU	Display Unit
GTV	Ground Test Vehicle
H/C	Helicopter
HUM	Health and Usage Monitoring
HUMS	Health and Usage Monitoring System
ILS	Integrated Logistic Support
LCC	Life Cycle Cost
MDDS	Maintenance and Diagnostic Display System
MGB	Main Gear Box
MMI	Marina Militare Italiana
NVM	Non Volatile Memory
TBO	Time Between Overhaul

TUM	Transmission Usage Monitoring
TVM	Transmission vibration Monitoring

Transmission Vibration Monitoring

The EH101 is the first helicopter designed with a Transmission Vibration Monitoring (TVM) completely integrated into the on-board avionic system.
TVM is a diagnostic tool capable of detecting failures well in advance with respect to other classical methods (e.g. temperature monitoring, chip detection) and therefore shall be seen not only as an additional monitoring method (not necessary to achieve the required level of safety but yielding anyhow an enhancement) but also as a special diagnostic tool (i.e., essential to achieve the "on-condition" maintenance, that is, the Time Between Overhaul removal).

The EH101 transmission system is fitted with 15 accelerometers spread over the gearboxes and the tail drive shaft bearing supports (Figure 1). The data are synchronously acquired on board (making also use of two azimuth sensors) and analysed in such a way as to yield 4 vibration indexes which are related to different types of failures/malfunctions. The vibration indexes are, in turn, compared against two thresholds in order to provide two types of arising:

- Maintenance
  on exceeding the lowest threshold: the air crew is not informed, but the information are stored into the on-board memory.

- Caution (military versions only)
  on exceeding the highest threshold: the crew are informed and the data stored in the on board memory as well

The data stored when the maintenance threshold is exceeded are transferred to a ground station and exploited to perform a trend analysis.
The vibration monitoring algorithms have been tested on the EH101 benches (transmission rig and Ground Test Vehicle, GTV) during the transmission type tests and fatigue tests and have proven their efficiency: they were indeed able to detect some types of malfunctions and failures well in advance with respect to the other monitoring devices. Despite the documented successful tests, the system cannot yet be considered as "mature" because it is necessary to:

- prove the reliability with respect to the changing transmission conditions
- further assess the false alarm rate.

Part of this proof has been carried out during the maturity phase trials (6000 flight hours); another part will be performed by using the data of the in service helicopters.

Helicopter Usage Monitoring

Usage monitoring is based on the principle that the life of the life limited items is an assessment made on the assumption of a design flight envelope, that is, helicopter mission profiles foreseen by the customer. In computing the lives, several pessimistic assumptions are made which lead to the application of safety (or ignorance) coefficients.
If, instead, the true flight envelope can be monitored, then the life expenditures can be computed with no need for pessimistic assumptions: the benefits in terms of LCC are obvious.

Monitoring of the true flight envelope implies the capability to detect all the manoeuvres performed by the helicopter during the missions; they range from simple events, such as a take-offs and landings, up to more complex manoeuvres, such as pedal or cyclic revelsals.
On the EH101 the recognition is performed by monitoring both flight parameters (e.g. speeds, attitudes, CG accelerations etc.) and systems' conditions (e.g. hook operations, vibration suppresser ON/OFF etc.)
The system is able to distinguish between almost 2000 micro-conditions which are then grouped in a smaller set of macro-conditions in order to be aligned with the load survey tests.

A subset of the helicopter usage monitoring is represented by the transmission usage monitoring (TUM). The transmission usage is kept under control by measuring the input torque to both the MGB and the tail drive line, and by computing the output torque to the MR mast. For each of the foregoing input and output torques, their range is divided up into a certain number of bands; the time spent in each band is then monitored and stored in the on-board NVM

Architecture

The HUM architecture can be roughly synthesized as depicted in Figure 2.
As previously stated, the EH101 HUM system is fully integrated into the on-board avionic system. The data generated by both sensors and equipment BIT (Built-In Test) are collected by a central computer in a non volatile memory (NVM): they can be then both/either browsed by using the on-board Display Unit (DU) and/or downloaded to a Data Transfer Device (DTD) in order to be, in turn, passed-on to a ground station called “MDDS” (Maintenance and Diagnostic Data System).

Display

The information stored in the NVM can be displayed to the crew by using the on-board CCU (Central Control Unit). The data display is designed to help the maintenance crew to carry-out the fault isolation and first line maintenance activities. Some of these information are directly exploitable as maintenance information (e.g. the ones relevant to failed BIT, see Figure 3), whilst others are for skilled personnel only.
In the case of the vibration monitoring, the threshold exceedances are displayed as shown in Figure 4 and Figure 5. The maintainer can assess the meaning of the parameters by looking up the maintenance manual.
The suggested method for exploiting the HUM data stored on board is, however, the data downloading to and display on the ground station, as explained in the next chapter

Ground Station

The availability of maintenance relevant data in digital form, i.e. the data stored in the H/C NVM, has forced the Industries to develop a tool able to read, manage, and properly exploit those data.
Such a tool has at least to

- read the on board non-volatile memory
- translate the data into maintenance information
- print out the job cards
- forecast/plan the scheduled maintenance
- exploit the usage information
- perform trend analyses
- manage the fleet

Some of the foregoings are tasks normally performed by the personnel in every maintenance organisation. A ground station offers therefore the possibility to pass from a classical “paper-based” to a modern computer-based maintenance management. But this is only one of the benefits.
Another big one is obtained from the exploitation of the usage monitoring information.
As previously stated the on-board system is able to detect the manoeuvres performed by each helicopter, that is, the real flight spectrum.
The ground station contains the algorithms able to transform the flight spectrum into life expenditure for each H/C lifed item. The lives of the items are therefore shown as either operating (or rotor turning) hours (Figure 6) or as cycles (e.g. landings), HUM hours (fig. 7), engine hrs, etc., depending on what parameter the item is sensitive to.

The possibility of having different metrics with appropriate thresholds allows the maximum exploitation of the helicopter items.

When the data are transferred to the ground station, an arising is generated. The arising can be either accepted or deferred. If accepted a MWO (Maintenance Work Order) can be issued (fig. 8), otherwise the arising is translated into an ADF (Accepted Deferred Fault) (Fig 9).
The details of the tasks provide information on the type and duration of the required job and this again allows a better management of the whole fleet.

Comments and Conclusion

What has been presented is just a brief overview of the capabilities offered by the HUM system as implemented on the EH101 Italian Navy (MMI) version. It must be said that the listed capabilities are not completely exploitable by all the customers. The Italian Navy, as all the armed forces, are in themselves engineering authorities and can therefore carefully assess the HUMS output and take full responsibility on deciding delays or un-necessity for maintenance tasks.
Quite different is the scenario for the civil customers. In this case the lives of the lifed items shall be defined in flight hours and the values reported in the chapter 4 of the maintenance manual: no derogation are allowed. In order to exploit the usage data collected by the helicopter, a different philosophy is adopted: the customer is asked to send the usage data to Agusta which, in turn, analyses them and decides if there is the possibility to extend the components lives (all or part of them). The chapter 4 of the maintenance manual is amended and re-certified with the involvement of the civil aviation authorities.

The capability to exploit the HUM data for the civil customers in a way similar to the one employed for the armed forces is presently the goal of the on going activities at Agusta.

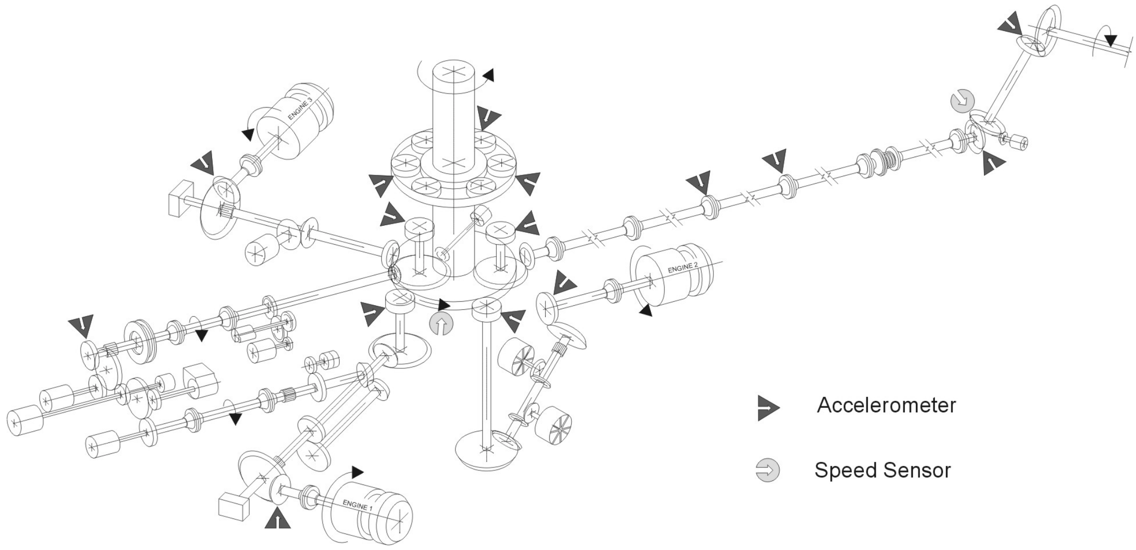

Figure 1: Vibration sensors layout

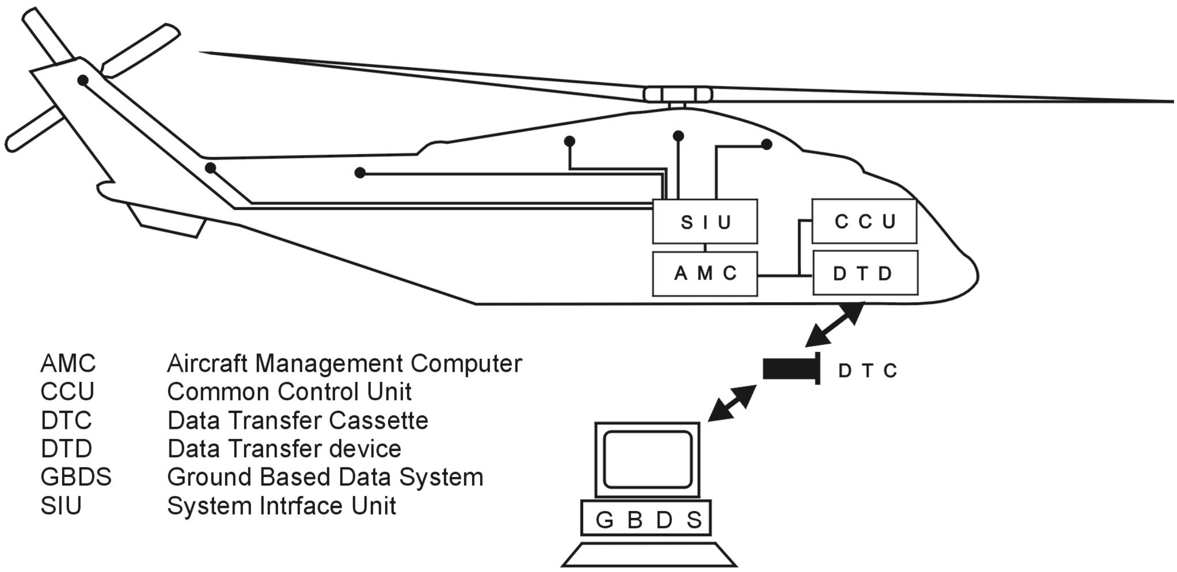

Figure 2: HUM architecture

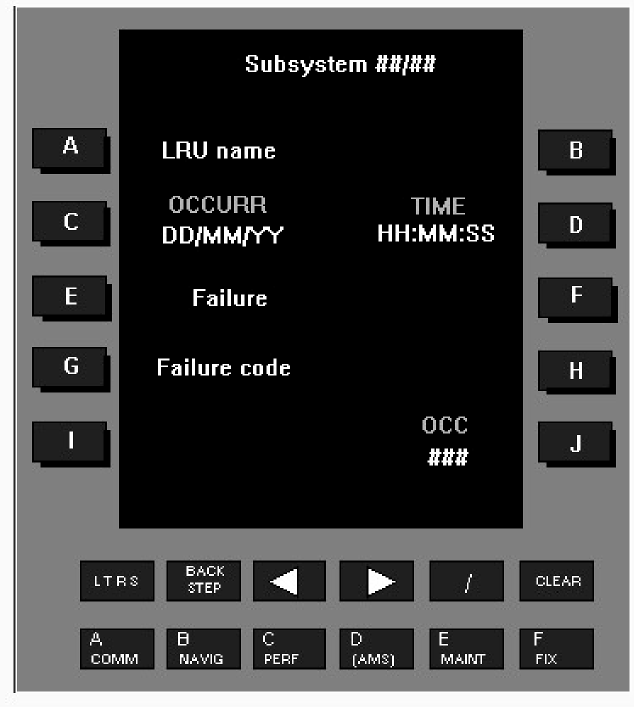

Figure 3

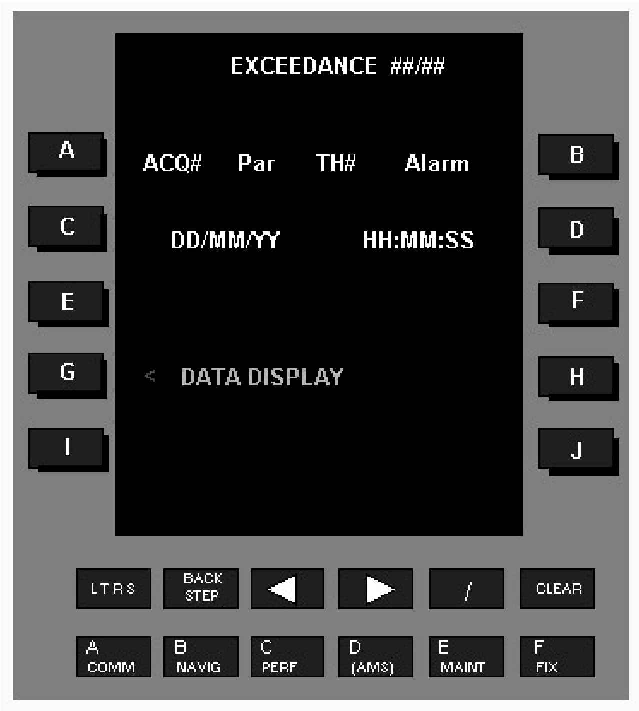

Figure 4

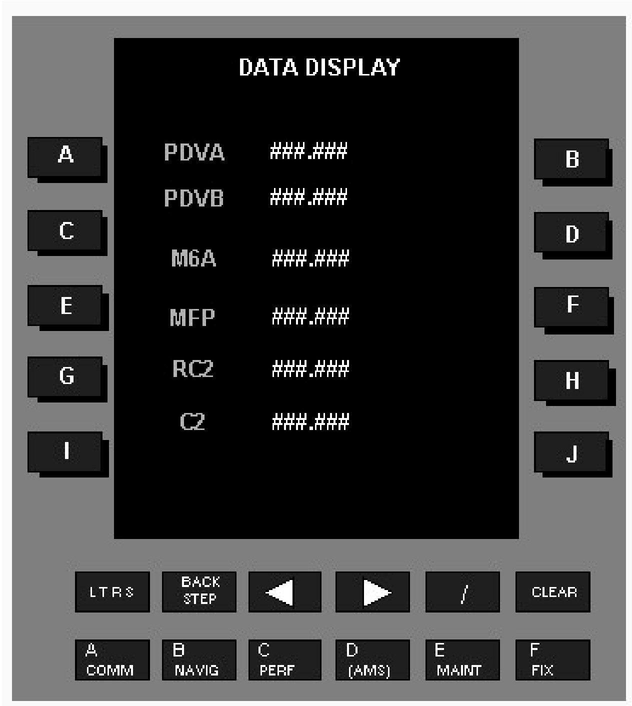

Figure 5

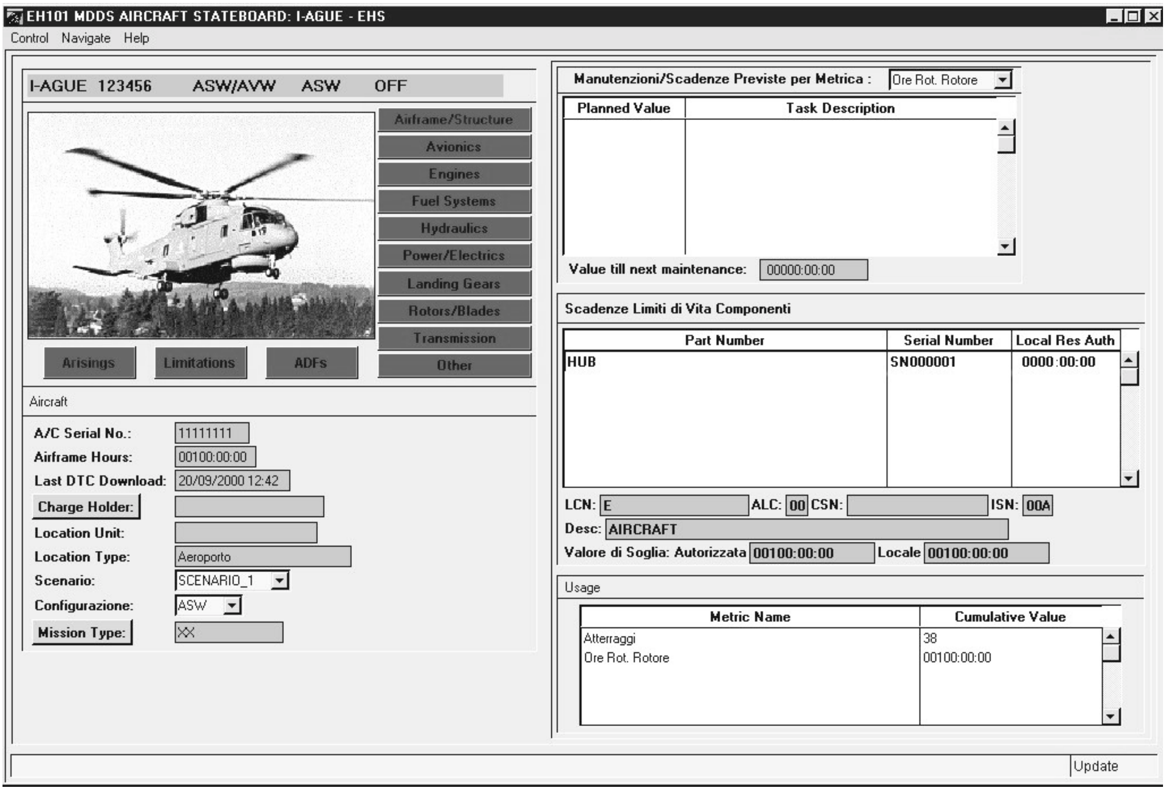

Figure 6

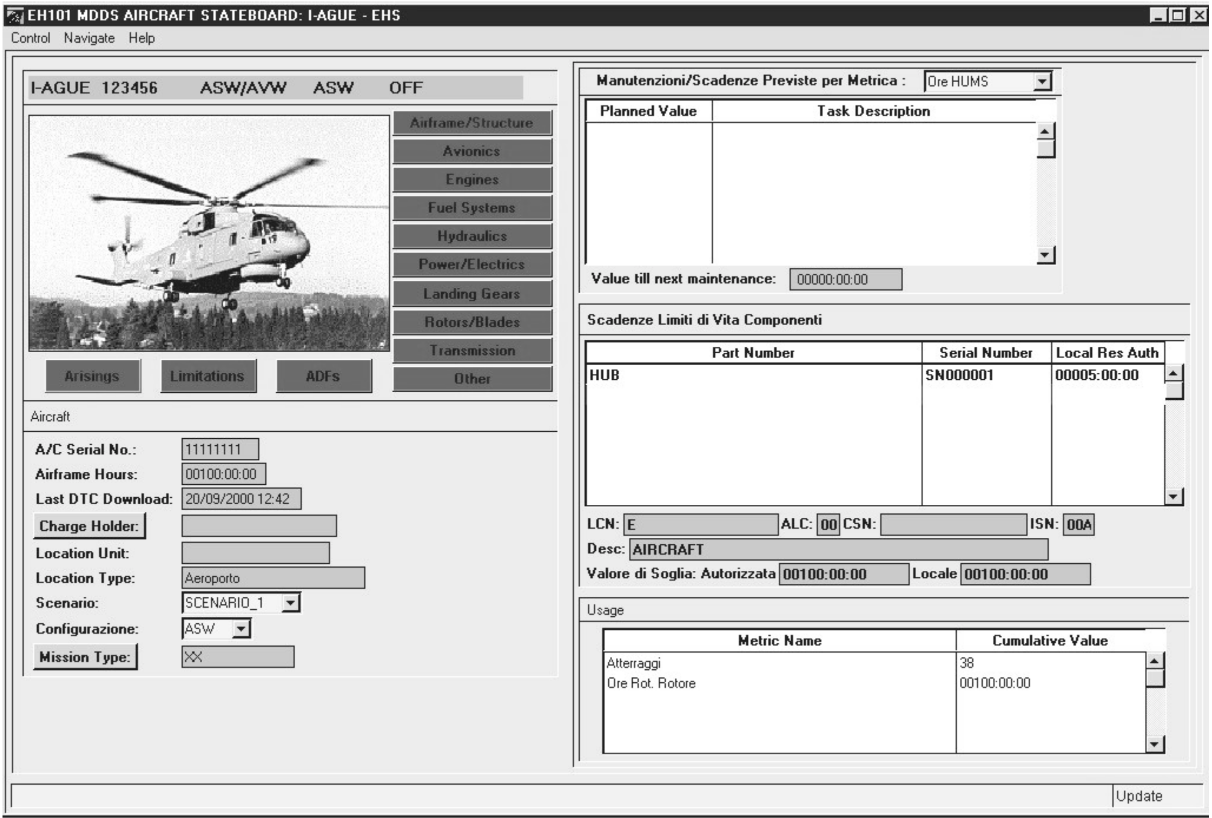

Figure 7

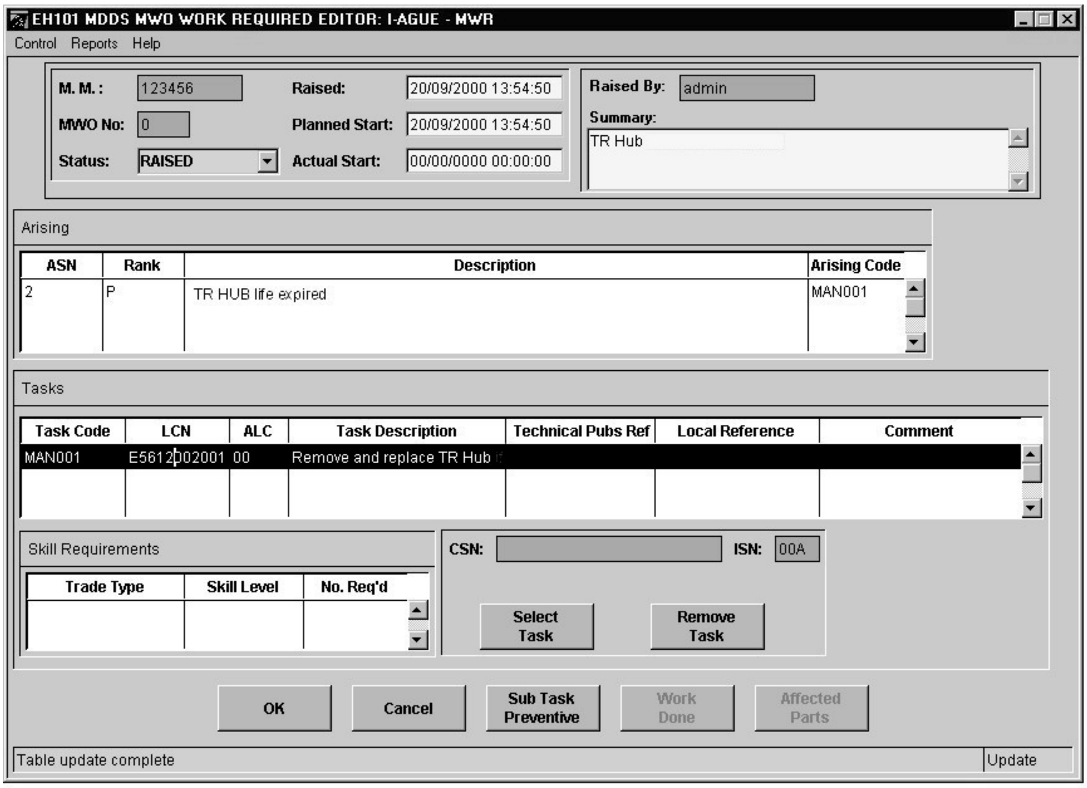

Figure 8

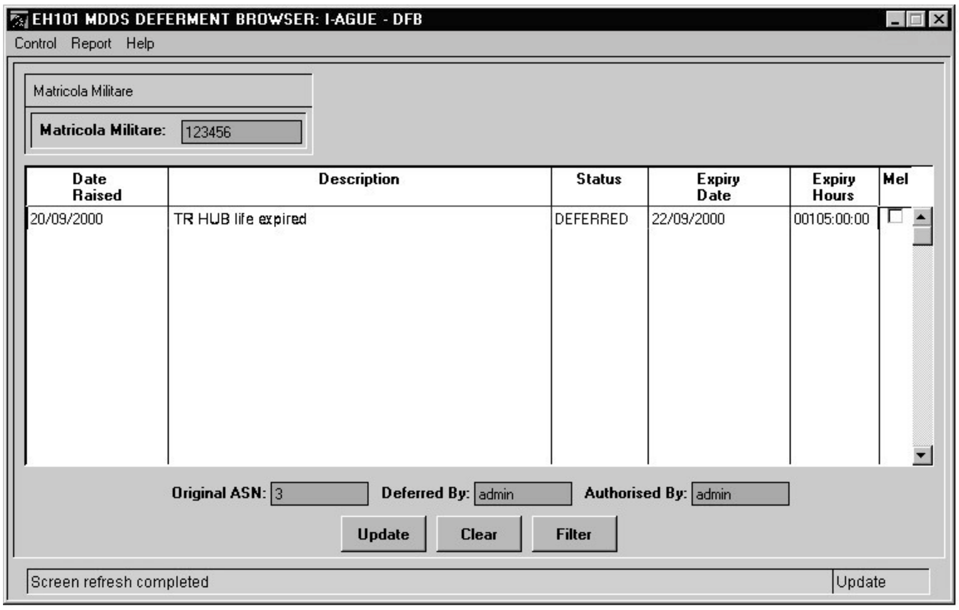
EH101 MDDS DEFERMENT BROWSER: I-AGUE - DFB
Control Report Help
Matricola Militare
Matricola Militare: 123456
Date Raised
Description
Status
Expiry Date
Expiry Hours
Mel
20/09/2000
TR HUB life expired
DEFERRED
22/09/2000
00105:00:00
Original ASN: 3
Deferred By: admin
Authorised By: admin
Update
Clear
Filter
Screen refresh completed
Update

Figure 9